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DESCRIPTION

LAMINATED COIL AND METHOD FOR PRODUCING THE SAME

Technical Field

The present invention relates to a laminated coil and a method for producing the laminated coil. More particularly, the invention relates to the shape of via holes in a laminated coil and a method for forming the via holes.

Background Art

As an example of a laminated coil, a chip inductor disclosed in Japanese Unexamined Patent Application Publication No. 2002-252117 is widely known, and the construction of the chip inductor is shown in Fig. 9, and Fig. 10 is the exploded perspective view thereof. As shown in Figs. 9 and 10, a related vertical lamination horizontal winding type chip inductor 11 has a structure in which a coil 13 wound in the direction Y perpendicular to the lamination direction X of a laminated body 12 is provided inside the laminated body 12. The coil 13 is constructed such that conductor patterns (belt-shaped conductors) 14 formed on laminated surfaces at fixed locations on the upper side and the lower side of the laminated body 12 are electrically connected through many via holes 15. Many of the via holes 15 are formed in the lamination direction X.

That is, as shown in Fig. 10, these via holes 15 are

formed such that through holes 17 are formed at fixed locations on each of ceramic green sheets 16 by laser radiation, etc., and these through-holes 17 are filled with a conductor such as conductor paste, etc. Then, as shown in Figs. 11 and 12, each through-hole 17 has a substantially round flat shape and its inner surface has the same angle of inclination (taper angle) along the lamination direction X. Moreover, the ceramic green sheets 16 constitute ceramic layers in the laminated body 12.

Moreover, Fig. 11 is a top view of the through-holes 17 and Fig. 12 shows the section of the through-holes 17 taken along line A - A in Fig. 11. That is, each through-hole 17 is constructed such that the diameter of the upper opening 17b is larger than the diameter of the lower opening 17a. Furthermore, at this time, the conductor patterns formed at the end portions on the upper side of the laminated body 12 are lead to the end faces and connected to external electrodes 18 formed so as to cover the end faces of the laminated body 12, respectively.

On the other hand, when the laminated body 12 is produced, many of the ceramic green sheets in which only via holes are formed are disposed in the middle of the lamination direction X. Then, plural ceramic green sheets 16 in which conductor patterns 14 and via holes 15 are formed are disposed above and below the above-described

ceramic green sheets 16. Furthermore, plural ceramic green sheets 16 in which no conductor patterns 14 or via holes 15 are formed are disposed above and below the above-described ceramic green sheets 16. Then, the ceramic green sheets 16 are attached by pressure in the lamination direction X and fired to obtain a laminated body 12. When the external electrodes 18 are formed on the end faces of the laminated body 12, a chip inductor 11 shown in Fig. 9 is completed.

Now then, in the chip inductor 11, since many via holes 15 are formed, the ratio of the resistance Rdc of the portion in which the via holes 15 are formed to the DC resistance value Rdc of the whole chip inductor 11 increases. It is not avoidable that the resistance Rdc of the whole element is affected by that. Thus, in order to prevent such a drawback, it is able to be considered that the flat shape of the via holes 15 is increased and, as a result, the inner volume of the via holes 15 is increased.

However, when the flat shape of the via holes 15 is simply increased, since the flat shape of the via holes 15 is substantially round, the spacing between neighboring via holes 15 in the axial direction of the coil 13 is narrowed. Furthermore, when the flat shape of the via holes 15 is made larger and the spacing between via holes 15 is appropriately kept, the number of turns of the coil 13 is reduced. As a result, a large impedance cannot be obtained.

The present invention has been made in consideration of such a drawback. It is an object of the present invention to provide a laminated coil in which, while the spacing between neighboring via holes in the axial direction of a coil is prevented from being narrowed, the inner space of each via hole can be increased and a method for producing the laminated coil.

Disclosure of Invention

A laminated coil comprises via holes formed in the lamination direction of a laminated body; belt-shaped conductors which are formed on laminating surfaces of the laminated body and fixed end portions of which are connected thereto by the via holes; and a coil wound in the direction perpendicular to the lamination direction. In the laminated coil, the via holes are formed in each ceramic layer constituting the laminated body and are through-holes, each being filled with a conductor, lying in a row in the lamination direction; and, in each through-hole, the difference between the diameter in the axial direction of the coil on the opening surface of one opening of the ceramic layer and the diameter in the axial direction of the coil on the opening surface of the other opening is smaller than the difference between the diameter perpendicular to the axial direction of the coil on the opening surface of one opening of the ceramic layer and the diameter

perpendicular to the axial direction of the coil on the opening surface of the other opening.

For example, in these through-holes, the inner portion corresponding to the axial direction of the coil has a sharper angle of inclination in the lamination direction than the inner portion perpendicular to both the axial direction of the coil and the lamination direction. In other words, the inner portion perpendicular to both the axial direction of the coil and the lamination direction in each through-hole has a duller angle of inclination in the lamination direction than the inner portion corresponding to the axial direction of the coil.

In the present invention, each through-hole has a substantially oval flat shape and the short-axis direction is in agreement with the axial direction of the coil.

A method for producing a laminated coil according to the present invention comprises the step of forming the via holes such that, after through-holes have been formed, the through-holes are filled with a conductor.

In the laminated coil of the present invention, in each through-hole constituting a via hole, the difference between the diameter in the axial direction of the coil on one opening surface of the ceramic layer and the diameter in the axial direction of the coil on the other opening surface is smaller than the difference between the diameter

perpendicular to the axial direction of the coil on one opening surface of the ceramic layer and the diameter perpendicular to the axial direction of the coil on the other opening surface. That is, in the laminated coil, since the via holes in which the angle of inclination is different at each direction on the inner portion are formed, when compared with the via holes in which the angle of inclination is the same all over the inner portion, the inner surface as a whole increases. As a result, the resistance Rdc of the portion where the via holes are formed is reduced.

Accordingly, the spacing between neighboring via holes in the axial direction of the coil is prevented from being narrowed and the number of turns of the coil can be effectively prevented from being reduced. As a result, it becomes possible to appropriately keep the spacing between via holes and maintain the number of turns of the coil, and the ratio of the resistance Rdc of the portion where the via holes are formed decreases. Accordingly, a large impedance can be secured.

In the laminated coil of the present invention, each through-hole constituting a via hole has a substantially oval flat shape and the short-axis direction is in agreement with the axial direction of the coil. When such through-holes are used, the via holes described above can be easily

formed as described above.

In the method for producing a laminated coil of the present invention, the angle of inclination on the inner portion of the through-holes can be easily controlled by adjustment of the energy distribution of laser light, and accordingly, the via holes described above can be easily formed.

Brief Description of the Drawings

Fig. 1 is a perspective view showing the construction of a chip inductor according to an EXAMPLE of the present invention.

Fig. 2 is an exploded perspective view showing the construction of the chip inductor according to the EXAMPLE.

Fig. 3 is an enlarged perspective view showing through-holes constituting via holes of the chip inductor according to the EXAMPLE.

Fig. 4 is an enlarged top view showing the through-holes constituting the via holes of the chip inductor according to the EXAMPLE.

Fig. 5A is an enlarged sectional view, taken along line A - A in Fig. 4, showing the through-holes constituting the via holes of the chip inductor according to the EXAMPLE.

Fig. 5B is an enlarged sectional view, taken along line B - B in Fig. 4, showing the through-holes constituting the via holes of the chip inductor according to the EXAMPLE.

Fig. 6 is a diagrammatical view showing the relation between a through-hole and the energy distribution of laser light according to the EXAMPLE.

Fig. 7 is an exploded perspective view showing the construction of a chip inductor according to a first modified example of the EXAMPLE of the present invention.

Fig. 8 is an exploded perspective view showing the construction of a chip inductor according to a second modified example of the EXAMPLE of the present invention.

Fig. 9 is a perspective view showing the construction of a chip inductor according to a related example.

Fig. 10 is an exploded perspective view showing the construction of the chip inductor according to the related example.

Fig. 11 is an enlarged top view showing through-holes constituting via holes of the chip inductor according to the related example.

Fig. 12 is an enlarged sectional view, taken along line A - A in Fig. 11, showing the through-holes constituting the via holes of the chip inductor according to the related example.

Reference Numerals

1 chip inductor (laminated coil)

2 laminated body

3 via hole

4 coil

5 through-hole

5a upper opening

5b lower opening

5c inner portion (inner portion corresponding to the axial direction of a coil)

5d inner portion (inner portion corresponding to the direction perpendicular to both the axial direction of a coil and the lamination direction of a laminated body)

14 conductor pattern (belt-shaped conductor)

16 ceramic green sheet (ceramic layer)

X lamination direction

Y axial direction of a coil

Z direction perpendicular to both the axial direction of a coil and the lamination direction of a laminated body

Best Mode for Carrying Out the Invention

In the present invention, it was made possible to attain the object of preventing the spacing between via holes neighboring each other in the axial direction of a coil from being narrowed and at the same time increasing the inner space of each via hole by establishing a three-dimensional structure of through-holes constituting via holes.

EXAMPLE

Fig. 1 is a perspective view showing the construction

of a chip inductor according to an EXAMPLE of the present invention, Fig. 2 is an exploded perspective view showing the construction of the chip inductor of the EXAMPLE, and Fig. 3 is an enlarged perspective view showing through-holes constituting via holes in the chip inductors of the EXAMPLE. Furthermore, Fig. 4 is an enlarged top view showing the through-holes constituting via holes, Fig. 5A is an enlarged sectional view showing through-holes taken along line A - A in Fig. 4, and Fig. 5B is an enlarged sectional view showing through-holes, taken along line B -B in Fig. 4.

Furthermore, Fig. 6 is a diagrammatical view showing the relation between a through-hole and the energy distribution of laser light, Fig. 7 is an exploded perspective view showing the construction of a chip inductor according to a first modified example of the EXAMPLE of the present invention, and Fig. 8 is an exploded perspective view showing the construction of a second modified example of the EXAMPLE of the present invention. Moreover, in Figs. 1 to 8, the same parts as in Figs. 9 to 12, are given the same reference numerals.

As shown in Figs. 1 and 2, a chip inductor 1 according to the EXAMPLE contains via holes 3 formed in the lamination direction of a laminated body 2 and conductor patterns (belt-shaped conductors) 14 in which fixed end portions are connected thereto by the via holes 3. In the laminated body

2 of the chip inductor 1, a coil is constructed by the via holes and the conductor patterns formed along the laminated surfaces of the laminated body 2 and connected to the via holes.

That is, the coil 4 of the chip inductor 1 is constructed such that conductor patterns (belt-shaped patterns) 14 formed on the laminated surfaces at fixed locations on the upper side and the lower side of the laminated body 2 are electrically connected through many via holes 3 formed in the lamination direction X. At this time, the conductor patterns 14 formed at the end portions of the laminated surfaces on the upper side of the laminated body 2 are lead out to the end faces of the laminated body 2, respectively, and the conductor patterns 14 are separately connected to external electrodes 18 formed so as to cover the end faces of the laminated body 2. Moreover, in Fig. 2, each of the conductor patterns 14 is constituted by three layers, but the conductor patterns 14 may be constituted by one layer.

On the other hand, as shown in Fig. 2, the via holes in this case are formed such that through-holes 5 are formed by laser radiation, etc., at fixed locations of each of ceramic green sheets 16 serving as ceramic layers of the laminated body 2 and the conductor-holes 5 are filled with a conductor such as conductor paste, etc. Furthermore, at this time, as

shown in Figs. 3 and 4, the through-holes 5 have an oval flat shape and their long-axis direction is a direction Z perpendicular to both the axial direction of the coil and the lamination direction X of the laminated body 2.

Moreover, in Figs. 3 and 4, only the upper openings 5a in the through-holes 5 formed in the ceramic green sheets 16 have a substantially oval flat shape. The lower openings 5b in the through-holes 5 in the ceramic green sheets 16 have a round flat shape. However, the through-holes 5 are not limited to such a construction. The lower opening 5b of each through-hole 5 may have a substantially oval flat shape, and it is desirable that the lower opening 5b also have a substantially oval flat shape in order to reduce the resistance Rdc in the portion where the via holes are formed.

In this case, as shown in Figs. 3 to 5, in the through-holes 5, there is provided a difference between the diameter in the axial direction of the coil 4 in one opening, that is, in the opening surface of the upper opening 5a of the ceramic green sheet 16 and the diameter in the axial direction of the coil 4 in the other opening, that is, in the opening surface of the lower opening 5b. The difference is made smaller than a difference between the diameter in the opening surface of the upper opening 5a in the direction Z perpendicular to both the axial direction Y of the coil 4 and the lamination direction X and the diameter in the

opening surface of the lower opening 5b in the direction Z perpendicular to the axial direction Y of the coil 4 and the lamination direction X.

That is, in the through-holes 5, the inner portion 5c corresponding to the axial direction Y of the coil 4 has a sharper angle of inclination (taper angle) than the inner portion 5d corresponding to the direction Z perpendicular to both the axial direction Y of the coil 4 and the lamination direction X of the laminated body 2. In other words, in the through-holes 5, the inner portion 5d in the direction perpendicular to both the axial direction Y of the coil 4 and the lamination direction X has a duller angle in the lamination direction X than the inner portion 5c in the axial direction Y of the coil 4.

In the case of the through-holes 5 having such a three-dimensional shape, when compared with the through-holes 17 having the three-dimensional shape shown in the related example, the inner surface increases as a whole and the inner volume also increases. Then, in the chip inductor 1 where the via holes 3 having the through-holes 5 filled with a conductor therein are provided, the resistance Rdc of the portion having a via hole 3 formed is smaller than that in the chip inductor 11 shown in the related example. As a result, the ratio of the resistance Rdc in the portion where the via holes are formed decreases in the whole resistance

Rdc of the chip inductor 1.

Next, a method for producing a chip inductor 1 according to the EXAMPLE is described. First of all, an aqueous binder such as polyvinyl acetate and water-soluble acrylic resin or an organic binder such as polyvinyl butyral is added to NiCuZn ferrite as a magnetic material. A dispersant, an antifoaming agent, etc., are added together with that, and then, a ceramic green sheet 16 is formed on a carrier film by using a doctor-blade coater and a reverse-roll coater.

In succession, through-holes 5 are formed at fixed locations on the ceramic green sheets by laser radiation. Then, as shown in Fig. 6, a through-hole 5 having a substantially oval flat shape, for example, a through-hole 5 having a substantially oval upper opening 5a and a substantially round lower opening 5b is formed by adjustment of the energy distribution of laser light. That is, at this time, when the energy of laser light exceeds a threshold value S, a hole passing through the ceramic green sheet is formed, and, if the energy rapidly changes around the timing where the energy exceeds the threshold value S, the angle of inclination on the inner surface of the through-hole 5 decreases. Furthermore, if the energy slowly changes around the timing where the energy exceeds the threshold value S, the angle of inclination on the inner surface of the

through-hole 5 increases.

Now then, when it is assumed that, in a chip inductor 1 in 3216 size, the number of turns of the coil 4 is 25.5 and the through-holes 5 having the upper opening 5a and the lower opening 5b, both having a substantially oval flat shape, are formed, the following dimensions are obtained. Although not illustrated, the dimension in the long-axis direction of the upper opening 5a of the through-hole 5, that is, in the direction perpendicular to both the axial direction Y of the coil 4 and the lamination direction X is 150 μm. The dimension in the short-axis direction, that is, in the short-axis direction corresponding to the axial direction Y of the coil 4 is 90 μm. Furthermore, the dimension in the long-axis direction of the lower opening 5b of the through-holes 5 is 110 μm and the dimension in the short-axis direction is 80 μm.

When constructed in this way, the dimension in the short-axis direction of the through-holes constituting the via holes which are filled with a conductor may be made smaller. Therefore, the cases where the spacing between neighboring via holes 3 in the axial direction Y of the coil 4 becomes too small do not occur, and the outer dimensions of the laminated body 2 do not become too large. Furthermore, in the chip inductor 1 in 3216 size, when the number of turns of 25.5 is secured, the maximum dimension in

the short-axis direction of the upper opening 5a of the through-holes 5 is 90 μm. That is, when the dimension in the short-axis direction of the upper opening 5a of the through-holes 5 increases, a short circuit is likely to occur because of diffused silver, cracks, etc., after sintering.

Next, a conductor paste having silver as the main component is prepared and the via holes 3 are formed such that the through-holes 5 formed in the ceramic green sheet 16 are filled with the conductor by screen printing of the conductor paste. Then, conductor patterns 14 constituting a part of the coil 4 are formed at fixed locations on the surface of the ceramic green sheets 16. After that, as shown in Fig. 2, a fixed number of ceramic green sheets 16 in which only via holes 3 are formed are disposed in the middle of the lamination direction X. A fixed number of ceramic green sheets 16 in which via holes 3 and conductor patterns 14 are formed are disposed above and below the ceramic green sheets 16, respectively.

Furthermore, a fixed number of ceramic green sheets 16 in which any of via holes 3 and conductor patterns 14 are not formed are disposed in layers above and below the ceramic green sheets 16, respectively, and then, after they have been attached by pressure in the lamination direction, they are cut so as to have fixed dimensions, they are

degreased, and they are fired to obtain a laminated body 2. After that, paste is fired on both end faces of the laminated body 2, and both end faces are plated with nickel and tin to form external electrodes 18, and then, as shown in Fig. 1, a chip inductor 1 is completed.

In the EXAMPLE, the chip inductor 1 in which one coil 4 is provided inside the laminated body 2 is a laminated coil, but it goes without saying that the application of the laminated coil of the present invention is not limited only to the above-described chip inductor 1. That is, a chip inductor, the structure of which is shown in Fig. 7, that is, in which two coils 4 are provided in parallel in the laminated body 2, is used as transformers and common mode choke coils. Such a chip inductor having two separate windings may be made into a laminated coil.

Furthermore, the present invention may be applied to a chip inductor, the structure of which is shown in Fig. 8, that is, in which two coils 4a and 4b, alternately disposed in the lamination direction X, are provided in the laminated body 2. The chip inductor is constituted by alternate windings. That is, in the chip inductor, the first coil 4a is constituted by conductor patterns 14a and via holes 3a (shown by a one-dot chain line in Fig. 8), and the second coil 4b is constituted by conductor patterns 14b and via holes 3b (shown by a two-dot chain line in Fig. 8). The

coupling coefficient between the two coils 4a and 4b in such a chip inductor of alternate windings is larger than that in the chip inductor of separate windings.

Then, in such a chip inductor of alternate windings, since many via holes 3 are aligned in the length direction of the laminated body 2, the reduction in the resistance Rdc because of the application of the present invention is remarkable.

Industrial Applicability

A laminated coil of the present invention can be applied to laminated coils such as chip inductors, lamination type composite LC parts, etc.